U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 3.

CULTURE

OF

THE SUGAR BEET.

BY

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PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1891.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF CHEMISTRY,
Washington, D. C., March 2, 1891.

SIR: The inquiries which the Department is daily receiving for information concerning the growth of sugar beets are so numerous as to render necessary the publication of a special circular of information. An elaborate discussion of the subject was presented in Bulletin No. 27, but the edition was so small as to render it impossible to send it to all who make inquiries. In the present publication an attempt will be made to present in a condensed form the data in possession of the Department concerning which the most frequent inquiries are made. No attempt will be made to elaborately discuss any of the points connected with the manufacture of beet sugar. Those who are particularly interested in this matter may still be able to obtain copies of Bulletin No. 27 before the original edition is entirely exhausted.

H. W. WILEY,
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Hon. J. M. RUSK,
Secretary of Agriculture.

THE CULTURE OF THE SUGAR BEET.

By H. W. WILEY.

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CLIMATIC CONDITIONS FAVORABLE TO THE GROWTH OF THE SUGAR BEET.

Experience has shown that the sugar beet reaches its highest development in north temperate latitudes. So far as the production of the beet with high tonnage is concerned, it is found that it will grow far to the south, but beets grown in such localities, upon the whole, are less rich in sugar and less suitable for the manufacture of sugar than those grown further north. It must be remembered, however, that the expressions north and south do not refer to any absolute parallels of latitude, but rather to isothermal lines, which in many cases run obliquely to the parallels of latitude and in some cases cross them almost at right angles. As a result of many years of careful experimentation, it may be said that as far as temperature alone is concerned the sugar beet attains its greatest perfection in a zone of varying width through the center of which passes the isothermal line of 70° F. for the months of June, July, and August. This zone is shown in a map in Bulletin No. 27.

This isothermal line, for the United States, begins at the city of New York and passes up the Hudson River to Albany; thence turning westward it runs near Syracuse and passes in a southwesterly direction, touching the shore of Lake Erie near Sandusky, Ohio; turning then in a northwesterly direction it passes into Michigan and reaches its highest point in that State near Lansing; then passing in a southwesterly direction it enters the State of Indiana near South Bend, passes through Michigan City, then in a northwesterly course continues through the cities of Chicago and Madison, reaching its highest point near St. Paul, Minnesota. Thence it passes in a southwesterly direction until it enters the State of South Dakota, thence it turns again northwest and reaches its highest point in Dakota just above the forty-fifth parallel of latitude, where it crosses the Missouri River. The isothermal line then turns almost due south, following very closely the one hundred and first degree

of longitude until it leaves the State of Nebraska near the northeast corner of Colorado; passing through a southwesterly direction through Colorado, it reaches, at Pueblo, almost to the one hundred and fifth degree of west longitude, whence it passes in a slightly southeasterly direction into New Mexico, turns to the west, and crosses the one hundred and fifth degree of longitude at about the thirty-second degree of latitude. Then turning westward it passes in a very irregular line through the States of California, Oregon, and Washington.

Extending a distance of 100 miles on each side of this isothermal line is a belt which, for the present, may be regarded as the beet sugar area of the United States. There are doubtless many localities lying outside of this belt, both north and south, in which the sugar beet will be found to thrive; but this will be due to some exceptional qualities of the climate or soil and not to any favorable influence of a higher or lower temperature. A mean temperature of 70° F. in the summer, however, must not be regarded as the only element of temperature which is to be taken into consideration. In those localities where the winters come early and are of unusual severity will be found greater difficulties in the production of sugar from the sugar beet than in those localities where the winters are light and mild, although the mean summer temperature of both localities may be represented by 70° F. As an illustration of this difficulty may be cited northern Nebraska and South Dakota where the winters are of great severity, and southern California where there is scarcely any winter at all.

The mean summer temperature of these localities is about the same, but the continuation of a summer temperature through the winter in southern California will greatly favor the manufacture of the beets. In northern Nebraska and South Dakota the beets which are to be manufactured during the winter time have to be protected by expensive silos. In southern California and other places similarly situated the beets can be protected without any covering, or at most with only a slight covering of leaves or straw. The season for planting in a mild climate is also longer; for instance, in southern California planting can commence as early as February and continue till June, thus giving a beet crop coming continuously into maturity from the 1st of August to the 1st of December. In other localities the planting must be accomplished in a short time, say from the 10th of May till the 1st of June. Before the first of these dates the ground will be too cold for planting, and after the second the season will be so late as to prevent the maturity of the beets before frost.

Although conditions of temperature must be taken into consideration in selecting sites for beet-sugar factories, yet in addition to the thermal conditions must also be taken those of rainfall. The sugar beet requires a certain amount of moisture in order to produce its normal crop. This moisture must be derived either from precipitation, in the usual way, or else the soil must be of that particular quality which will allow subter-

ranean moisture to reach the rootlets of the plants. Soil of this latter kind appears to exist in many localities in California where beets are grown absolutely without rain. The porous and sandy soil surrounding many of the western rivers, such as the Platte River in Nebraska and the Arkansas River in Kansas, also appear to furnish a sufficient amount of subterranean moisture to produce a good crop in connection with the rainfall, of which little is expected in those localities during the summer months. We should, however, endeavor to secure localities for the growth of the sugar beet where we may expect an average summer precipitation of from 2 to 4 inches per month. There are many conditions of agriculture under which the beet becomes quite independent of extremes of precipitation. The beet may thrive with very little rainfall or with a great deal, if properly cultivated in suitable soil.

VARIETIES OF BEETS.

All kinds of sugar beets are botanically identical with the common garden beet, *Beta vulgaris*. The differences in varieties have arisen by reason of special selection and culture, producing a pure strain of some valuable peculiarity in the beet. These accidental valuable qualities, by careful selection, have become fixed, and are associated with certain external properties which have thus come to be regarded as distinguishing characteristics.

The shape and size of the beet, its color, the character of the foliage, whether erect or spreading, etc., are the most frequent marks of distinction. The beets are also frequently designated by the names of those who have developed them, or by the name of the town or locality in which they have been grown, or by their color.

Among the more frequently occurring varieties grown in Europe may be mentioned the Vilmorin Improved, Klein Wanzlebener, Improved Klein Wanzlebener, White Excelsior, White Imperial, Simon Le Grande, Florimond and Bulteau Desprez Richest, Brabant Sugar Beet, Rose Imperial, etc.

The two varieties which have been most widely grown in this country are the Vilmorin Improved and the Klein Wanzlebener. The certainty that the seed has been grown according to the most scientific methods is of greater importance to the beet grower than the variety. The beet has reached such a high state of perfection as to make the least degree of laxity in its treatment exceedingly dangerous to its qualities.

SOIL.

The sugar beet does not require a particular kind of soil for its proper production. In general, soils are described for practical purposes as clayey, sandy, loamy, or alluvial soils; all of these soils will produce beets. The black prairie soils also have been found, with proper cultivation, to produce excellent beets. Generally, the least favorable soils

for the sugar beet are a stiff clay, which is cultivated with difficulty and readily packs under the influence of hard rains and hot suns, and virgin soils or those especially rich in organic matter or alkaline salts. Perhaps the best soil may be described as a sandy loam; a soil containing a happy equilibrium between organic matters, clay, and silica.

In general it may be said that any soil which will produce a good crop of Indian corn, wheat, or potatoes will, under proper cultivation, produce a good crop of sugar beets. The soil on which sugar beets are grown, however, should be reasonably level, and this being the case it should be well drained. Natural drainage on level soil being somewhat deficient, it is most imperative that tile drainage be practiced. It would be useless to attempt to raise sugar beets on level land without tile drainage, especially in a rainy season.

FERTILIZATION.

Happily, in most American soils there is still sufficient natural fertilization to produce a good crop of sugar beets; while in the soils of Europe, where sugar beets have been grown for years, the farmers must depend on fertilizers to insure a remunerative crop.

Two kinds of fertilizers are employed: stall manure from the farm, and artificial manure generally known as commercial fertilizers. For general purposes, stall manure is better. It should be applied, in a well-rotted condition, in the autumn before the ground is plowed. The quantity per acre depends, of course, on the fertility of the soil; but in any case it is not best to apply a very heavy dressing. In poor soils it is best to apply the fertilizer for several years in succession, rather than to apply enough at once to bring it up to the required state of fertility. Too copious an application of stall manure is apt to produce overgrowth in the beets, which makes them ill-suited to the manufacture of sugar. If the fertilizer be applied in an unrotted condition, it is apt to seriously injure the crop in case of dry weather.

Of commercial fertilizers three classes are employed, containing respectively nitrogen, phosphoric acid, and potash. In some instances these three elements are found combined in the same commercial fertilizer. Nitrogenous manure should be applied with great care to sugar beets. It tends to produce a very heavy growth of the beet, and thus to diminish its content of sugar. Potash and phosphoric acid can be applied with great freedom to beet fields; they act much better in conjunction than when applied separately.

The principles of fertilization depend upon the fact that the soil should have returned to it all that the harvest has removed in respect to mineral substances and nitrogen.

Nothing can be more certain than that a soil to which this restoration is not fully made will gradually lose its faculty to produce plants in normal quantity and composition. Culture experiments with artificial food liquids have not been carried so far with the beet as with some

other plants and, therefore, the dependence between the composition of such liquids and the evolution of the beet has not yet been determined. The basis is also wanting whereon the direct working of the manure on the beet can be predicted; and here is met the well known difficulty of getting the manures into those layers of the soil from which the beet chiefly draws its supplies.

Since experience has taught that beets raised on fields freshly manured with stable manure are inferior for purposes of manufacture, the rule has long been established that not the beets but the previous crop should be fertilized, or that the beets should be raised in rotation as the second or even third crop. Unfortunately this rule, so important to the factories, is not always observed, and as a consequence of heavy manuring heavy crops have been produced, but at the cost of diminished sugar content or lessened price. This rule applies especially to stable manure and night soil, as well as to Chili saltpeter, the misuse of which has had such serious consequence for factories, but not to phosphatic manures, which usually exert a favorable influence upon the crop.

The constituents to be taken into account in the necessary restitution to the soil for beets are potash, phosphoric acid, magnesia, and nitrogen. Following are the quantities of these constituents in 1,000 pounds of beets and beet leaves, averaged from numerous analyses:

Constituents.	Roots.	Leaves.
	Pounds.	*Pounds.*
Potash	3.3	6.5
Phosporic acid	0.8	1.3
Magnesia	0.5	3.0
Nitrogen	1.6	3.9
Total ash	7.1	18.1

It will be seen from the relation between the roots and leaves that the amounts abstracted by the latter are considerably greater and deserve especial consideration in case the leaves are not left in the field. From this point of view the leaves should be left in the field. It is certain that a complete restitution can not be made otherwise. The form in which the above-mentioned plant constituents shall be returned to the soil is established for phosphoric acid and magnesia, and partly for nitrogen; superphosphates, with greater or less content of phosphoric acid, or with addition of nitrogenous element, are of universal application. As has been shown by direct investigations, the magnesia is nearly all returned in the press cakes from the factory, though a more uniform distribution is much to be desired.

The soil ingredients most essential for successful production of the sugar beet are nitrogen, phosphoric acid, potash, lime, and magnesia.

Most soils contain a sufficient quantity of magnesia, and the press cakes from the factory, which should be returned to the soils, will supply any deficiency. The same is true in regard to lime, although there are soils in which the supply of lime is naturally deficient. Such soils

would be benefited by an application of land plaster, burned lime, or ground shells. Phosphoric acid and potash are supplied in the form of ordinary commercial fertilizers, as ground bone and kainite or as superphosphate combined with some potash salt. Of the various potash compounds found in natural deposits none are to be preferred to others; preference is due only to compounds with organic substances. Consequently the molasses, or its residue after distillation and the liquors of the molasses-working processes, all rich in potash, are themselves most valuable materials for potash fertilization and should be carefully preserved for such use. It must not be supposed, however, that the demand for potash will be satisfied by returning to the soil the molasses from the crop of beets in the form of waste products. Aside from the leaves, for which if taken from the field a largely increased potash return must be made, the molasses itself does not represent the entire amount of potash taken. Factories which produce raw sugar sell with it also potash, and in all factories the waste waters carry potash compounds sufficient to account for the difference between the amount of potash in the beets and in the molasses.

Phosphoric acid is best supplied in the form of ground bone, superphosphate, or basic slag from the blast furnaces. Nitrogen may be supplied in the form in which it exists in ground bone or from the refuse of the slaughter houses in the form of dried blood and tankage, or as cotton-seed meal or oil cake, or as nitrate of soda.

As for the relation which the quantity of material returned should bear to the quantity abstracted, it may be said in general that it is desirable to return as much nitrogen, one and a quarter to one and a half times as much potash, and two and a half times as much phosphoric acid as has been abstracted. The greater additions of potash and phosphoric acid have no disadvantageous effects upon the crop. Direct investigations in regard to the relation between the sugar and potash in consecutive crops for many years have failed to give the least ground for a contrary conclusion. But it must not be expected, on the other hand, that increasing fertilizations, especially potash fertilization, will produce proportionately increasing crops, as has been asserted by some.

EFFECT OF NITROGENOUS MANURES ON THE QUALITY OF THE BEET.

The opinion has generally prevailed among beet-growers during late years that heavy nitrogenous manuring, especially with nitrate of soda, produces no injurious effect on the quality of the beet. This opinion was based on the fact that in such beets the sugar per cent was only slightly diminished. Nevertheless the quality of a beet may be impaired even with little or no diminution of the sugar content by reason of the increase of the percentage of non-sugars present.

It has been shown that heavy manuring with nitrogenous substances greatly injures the quality of the beet for sugar-making purposes. The

apparent coefficient of purity of the juice is also frequently misleading since it takes no account of the nature of the non-sugars present.

The real purity of the beet is also to be distinguished from the apparent purity of the juice. The real purity of the beet is obtained by dividing the percentage of sugar in the beet by the total solid matter therein; the apparent purity of the juice by dividing the percentage of sugar therein by the apparent percentage of solids as indicated by the Brix spindle. Judicious fertilizing with nitrate of soda, however, is beneficial.

ROTATION.

Beets do best after wheat or some other cereal. It is true that soils on which beets have not been grown, as the soils of this country, may produce beets for several years without harm. Nevertheless, proper rotation is always desirable.

A good scheme of rotation is, first wheat, then beets, then clover, one crop of which is cut for hay and the second crop plowed under, then potatoes, wheat, and beets in the order mentioned. By this method and a judicious use of stall manure and commercial fertilizers, the fertility of the soil can be maintained and even increased. Beets should follow wheat or a cereal crop, because this crop being harvested early leaves the ground ready for autumn plowing, a prerequisite to successful beet culture.

PREPARATION OF THE LAND FOR PLANTING.

The field in which beets are to be planted should be selected and plowed in the autumn to the depth of at least 9 inches. The plow in each furrow should be followed by a subsoiler, which will loosen the soil to the depth of 6 or 7 inches more. A convenient subsoil plow is shown in Fig. 1. Each field to be planted in beets should thus have the soil

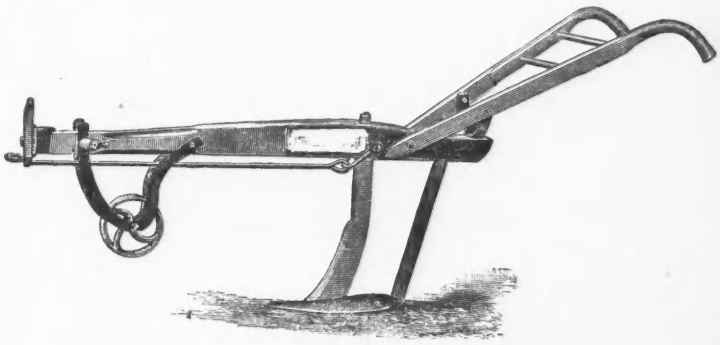

FIG. 1.

prepared by thoroughly loosening it to the depth of from 15 to 18 inches. The land being exposed through the winter becomes quite mellowed,

and in the spring can be prepared for planting by a simple preparation of the surface. This should be done by a thorough cultivating until the surface of the soil is reduced to perfect tilth, and it then can be marked out for planting. No further preparation is necessary. It is desirable, however, that each portion of the field to be planted should be thoroughly prepared immediately before the planting takes place. For instance, if the planting is to be made on a given day, the soil should be thoroughly prepared on the previous day. Thus all weeds and grasses which have started to grow are killed, and the beets have an even chance with the weeds for growth. If, on the other hand, the soil be prepared several days or even a week before planting, the weeds and grasses get a good start and it is difficult then for the beets to thrive.

PLANTING.

The beets may be planted either by hand or by drill. Hand planting is preferred when a very small plot is to be put in beets, but where a field embracing several acres is to be planted, hand planting becomes too slow. In such cases planting by drill is best. Almost any garden drill can be adapted to use with beet seed. A special drill for sugar beet seed is furnished by the Deere–Mansur Company, of Moline, Illinois. It is represented in Fig. 2. The form of drill represented in

FIG. 2.

Fig. 3 may also be used. In hand planting the beets may be placed in hills, several seeds being planted in each hill, and thus the cultivation of the beets be facilitated. In planting by drill it is necessary to plant from 15 to 20 pounds of seed per acre; in planting by hand from 10 to 15 pounds will be found sufficient.

The beets should be covered to the depth of one-half to one and one-half inches, according to the condition of the soil. If the soil be moist and in excellent condition, the beet seed should not be covered more

FIG. 3.

than half an inch. If, on the other hand, the soil be very dry, they should be covered to the depth of one and a half inches.

CULTIVATION.

As soon as the beets are large enough to mark the rows, cultivation with the horse or hand hoe may be commenced. This is essential if the grass and weeds appear above ground at the same time.

When large fields are cultivated, the horse hoe made by Bajàc, of Paris, shown in Fig. 4, may be used. For smaller fields a similar apparatus, drawn by hand, may be employed. Convenient instruments of this kind are shown in Figs. 5 and 6. This plow frees the spaces between the rows of beets from weeds and yet prevents the growing beets from being covered by the loose soil.

When the beets show four leaves, the process of thinning should take place. If the rows be 18 inches apart, a vigorous plant should be left every 8 to 10 inches. Careful selection should be made and all the puny plants destroyed. It is better to save the vigorous plants even if regular intervals are not preserved, but no space should be left greater than 12 to 15 inches in extent. Much of the thinning work can be done by a narrow hoe, but where the plants are very close together, at the place where the preserved plant is to grow, the work must be done by hand. It is well to have a thorough hand hoeing at the same time, and the subsequent cultivation, in most seasons, may be carried on with horse-power.

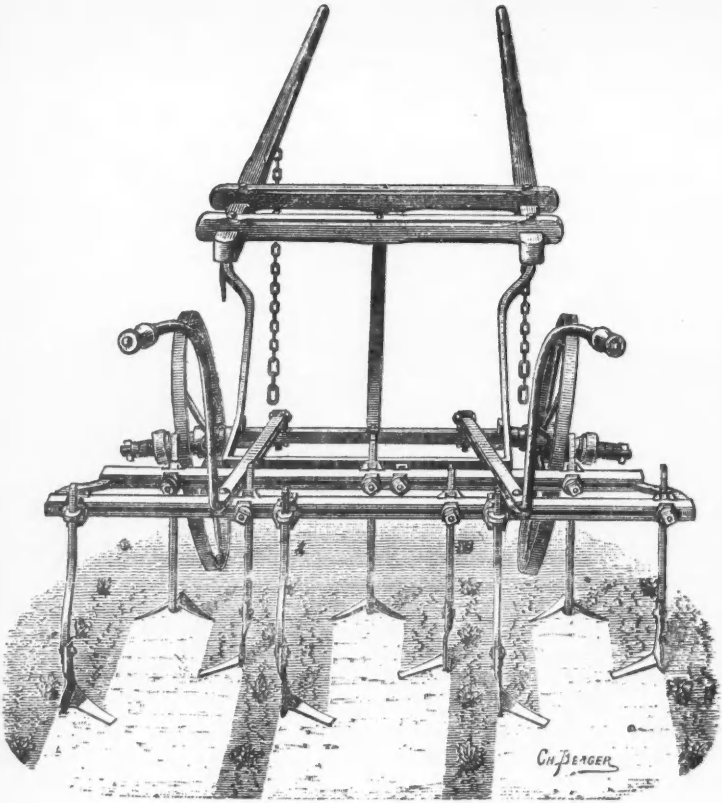

FIG. 4.

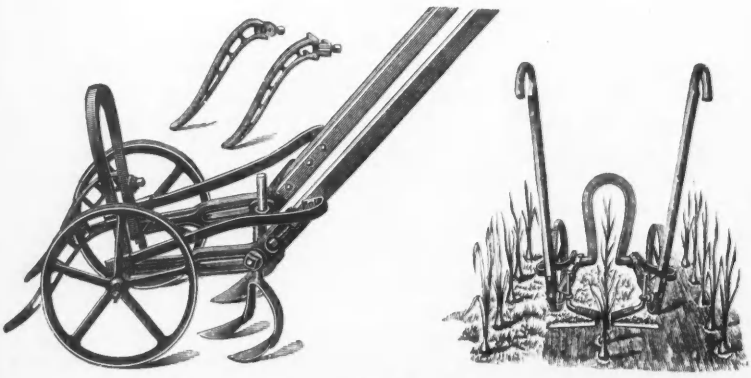

FIG. 5.

When the beets are more advanced a few deeper cultivations may be desirable, and for these any good narrow cultivator may be used for

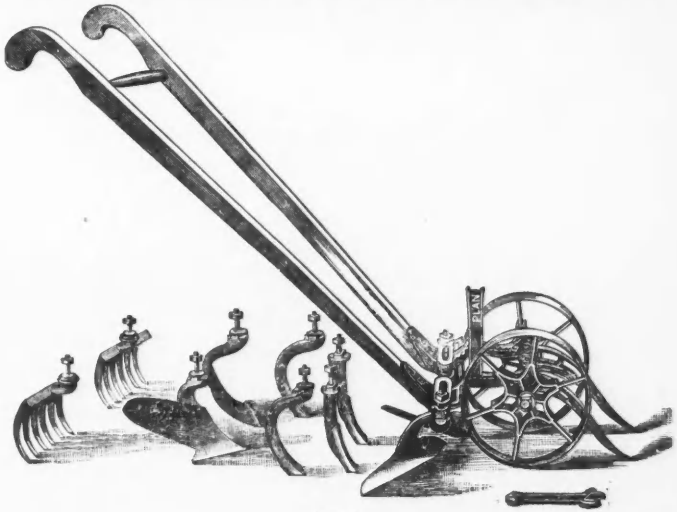

FIG. 6.

single rows or wider ones for double rows. The instruments shown in Figs. 7 and 8 will be found suitable to this kind of work.*

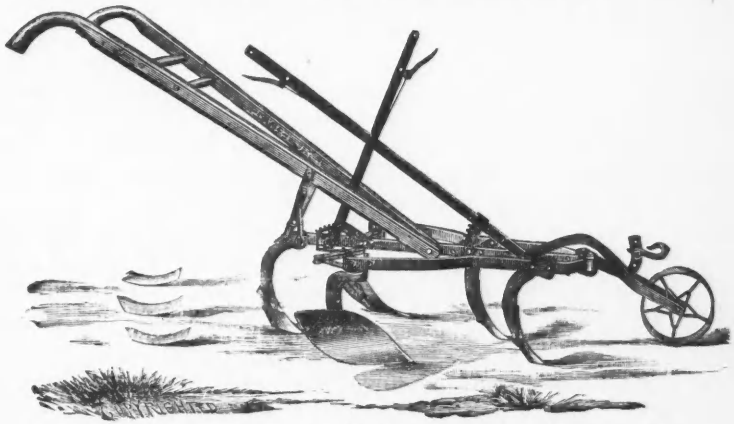

FIG. 7.

The cultivation in all cases should be conducted for the double purpose of keeping the beets entirely free from weeds and for preserving the proper tilth of the surface of the soil. It may be said that at least

* Figs. 6, 7, and 8 are from electrotypes furnished by S. L. Allen & Co., of Philadelphia; Figs. 1 and 3, by the Moline Plow Co., and Figs. 2 and 5 by the Deere-Mansur Co..

once a week during the period of growing, lasting from 6 to 8 weeks, the beet field should be cultivated. If the season be very dry, more frequent cultivation will be found useful. The final cultivation should

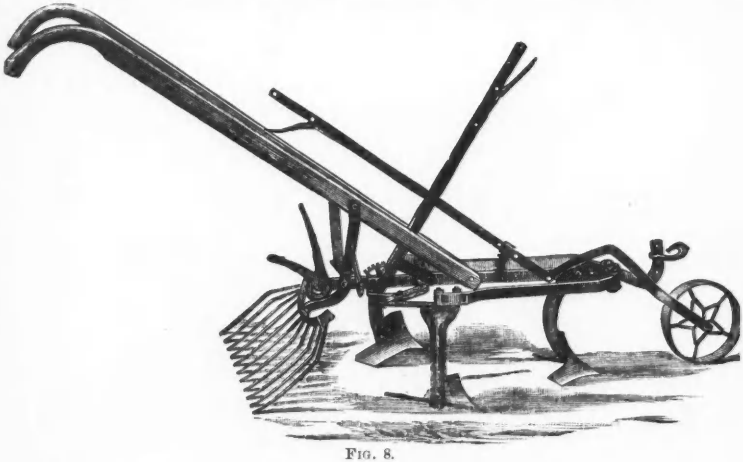

FIG. 8.

leave the soil practically level. During cultivation care should be taken not to injure either the leaves or the root of the beet, and when the foliage of the growing crop begins to cover well the surface of the soil cultivation may be suspended.

COST OF GROWING BEETS.

The cost of growing an acre of beets depends on so many varying factors as to render it impossible to give an estimate which is reliable for every locality. The differences in rent of land, cost of labor, methods of culture, etc., require that any estimate which may be given should be revised for almost every locality. The following estimate of maximum cost per acre is based on the supposition that land is worth $75 per acre, labor $1 per day, the yield 15 tons per acre, and that the distance to the factory is 1 mile:

Rent of land	$5.00
Plowing, subsoiling, and preparing for planting	5.00
Fertilizers	10.00
Cost of seed	2.25
Planting	1.75
Hoeing and thinning	6.00
Cultivating with horse-hoe five times	5.00
Harvesting	5.00
Topping	12.00
Delivering to factory	7.50
Total	59.50
Value of 15 tons, at $4.50	67.50

In the above estimate has been included the cost of the best culture and a reasonable application of fertilizer. It is probable that the actual

cost to our farmers for the first few years of the beet industry will not exceed $45 or $50 per acre. The price paid for the beets is also a minimum. It will not be long before first-class beets, delivered to the factory, will be worth at least $5 per ton.

It is therefore believed that, accidents of season aside, a net profit of from $8 to $15 per acre may be expected from the proper culture of the sugar beet in localities near a factory.

In contrast with the above estimate I give the actual figures submitted by Mr. J. Thomssen, of Hall County, Nebraska, in a letter published in the Prairie Farmer, on the 3d of January, this year. The cost is given for a field of 5 acres; the items are as follows:

Fall plowing, at $1 per acre	$5.00
Plowing in spring, at $1.25	6.25
Rolling twice, once before and once after planting	1.50
Planting by hand, at 75 cents per acre	3.75
Cultivated with hoe, at 75 cents	3.75
Thinning, at $10	50.00
Hoed by hand three times and weeding necessary at time of hoeing	90.00
Cultivated by horse twice, at 75 cents	7.50
Running over with hoe to clear from remaining weeds	3.75
Total	171.50

Dividing this by 5 gives a total of $34.30 per acre.

As will be seen from the above, Mr. Thomssen makes no allowance for the rent of the land, used no fertilizers, and gives no estimate of the expense of harvesting and hauling to the factory. But his field was hoed by hand three times, which with the proper implements is more than is necessary, one good hand hoeing being sufficient.

The average cost per acre of raising sugar beets in France is given in the following detailed estimate from figures furnished by M. E. Du Fay, of Chevry, Cossigny, France:

Farmyard manure	$28.00
Fertilizers	12.00
Spreading manure	.60
Spreading fertilizers	.25
First plowing	1.60
Harrowing and rolling after plow	.64
Plowing and subsoiling	4.60
Two scarifyings	2.00
Two harrowings	.64
Two rollings	.64
Cost of seed	3.00
Sowing of seed	.80
Harrowing and rolling again	.64
Three times hoeing with horse	2.40
Hoeing by hand	4.80
Harvesting by hand	4.00
Harvesting by machine	1.60
Carting to factory	2.40
Total	70.61

To the figures stated are still to be added the rent of land and taxes, $9.40, making a total of $80.01.

The charge for harvesting is very low, from the fact that the topping of the beets is performed by women and children, whose average wages probably do not exceed 15 cents a day, much less than the estimates call for in this country, while the charge for fertilizers is much greater than we should need on our soils for some years to come. The average yield per acre obtained by M. Du Fay is 25 tons, showing the value of intensive farming.

Mr. J. B. Henderson, of Alameda, California, reports the cost of growing and harvesting 10 acres of beets at $614.83, or $61.48 per acre. He was 1 mile from the factory. Mr. A. F. Richardson, of the same place, residing 2 miles from the factory, reports the cost of 11 acres at $535.04, or $48.64 per acre.

It is not wise to underestimate the actual cost of growing the beets, for this will lead the farmer to expect large profits which often in practice give way to actual deficits.

HARVESTING.

The time for harvesting varies in different localities. In California it is said that the beets planted in February are ready for harvesting by August. In general it may be said that beets planted the first week in May will be ready for harvesting about the 20th of October. Harvesting should be postponed to as late a date as possible, provided the beets are in no danger of a second growth. The leaves of the ripened beet change from a rich green to a yellowish green, become drooping and applied closely to the earth, and many of them die. The harvesting is best accomplished by first loosening the beets in the soil and then removing them by hand. For loosening the beets, the apparatus shown in Fig. 9 may be employed. It can be used only when the rows are perfectly straight and the beets of a reasonably uniform size. The teeth of the apparatus are sunk deep enough into the earth to catch the beet at about its middle part. The beets are forced back through the teeth of the apparatus, which approach more nearly together in the rear, and on account of the angle at which the teeth are planted, are lifted and the tap roots broken. After the passage of the harvester the beets are easily lifted out by means of their leaves.

The next operation consists in removing the neck. This is done by a large knife, and the top of the beet, called technically its neck, is cut off so as to remove, with the top, that portion of the beet to which the stems of the leaves have been attached.

The object of removing this portion of the beet is to prevent the mineral salts, which have accumulated in large quantities therein, from entering the factory. These mineral salts exercise a very deleterious influence on the crystallization of the sugar and, therefore, should be

removed. They are well fitted for fertilizing purposes and are of more value when left upon the soil than when removed to the factory.

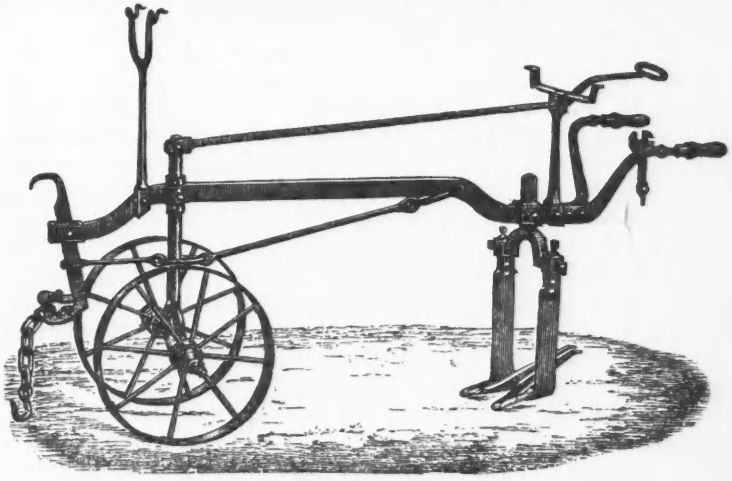

FIG. 9.—Beet harvester for one row.

The removal of the tops of the beets is a tedious process which, in Europe, is performed by women and children. In this country the process of topping the beets will prove much more expensive than in Europe. It is probable that some mechanical device will be invented by which the beets can be topped, thus saving a large expense. So far as we know at the present time, however, this topping must be done by hand.

When the beets are topped they are thrown into piles, and the tops thrown over the beets to protect them from the sun or frost until they can be delivered to the factory.

The beets are best delivered to the factory in dump carts, which permit of their quick unloading. It is not customary for the farmers to silo their beets except in the simple manner indicated above.

SILOING.

When beets are to be preserved for manufacture during the winter months or for the production of seed, they must be carefully protected against frost. The simplest and the easiest method is to place them in piles and cover them with earth, not too deeply, for if they become too warm in the silo they rapidly lose in sugar content. When first siloed, say about the first of November, they should be covered with only a slight layer of earth; as the cold of winter becomes more intense this covering can be increased. In some localities only a slight covering of straw is necessary to protect the beets, as, for instance, in California, and in other localities the deepest covering of earth might not exceed 6 inches,

which would be entirely sufficient to preserve the beets from freezing. In other localities, such as in the Dakotas, Minnesota, and Wisconsin, it is probable that the beets would have to be covered to the depth of 2 feet, or even 2 feet and 6 inches, to protect them from frost.

Siloing is usually done by the factory, as it would be very inconvenient to deliver beets from a distance to a factory in the middle of winter.

In most localities in the beet-sugar region of the United States it is probable that the harvesting and delivery to the factory could be entirely completed by the middle of November; although in some seasons there would be no danger whatever in leaving the roots in the earth until the 1st or even the 10th of December.

PRODUCTION OF SEED.

The production of seed is one of the most important operations connected with the sugar-beet industry. On the care and skill which are displayed in this process depend the improvement and maintenance of the sugar-producing qualities of the beet. There are many different methods employed for producing seed which grows the richest sugar beets, but there will be mentioned here only a general outline of the principles which underlie the process. The beets which are to be preserved for seed are called "mothers" and are carefully siloed in the manner already indicated. They are selected at the time of harvesting from specially grown beets or from fields of beets which have shown particularly good qualities on analysis. The size of the roots selected for mothers should be about the average of the best sugar beets, viz, from 20 to 24 ounces. Smaller beets than these would show a higher content of sugar, but it is not wise to produce a race of small beets by selecting the seed from the very smallest and richest beets grown. The size of the mothers having been decided, the beets are next selected for their shape and external appearance. Those regular in shape and smooth in external form are to be preferred. Roots of irregular shape, or with more than one tap root should be rejected.

The beets to be preserved for mothers are harvested with unusual care to avoid injury. The neck is not cut away, but the leaves are removed by cutting off the stems without injuring the neck of the beet.

The siloing should be of such a nature as to entirely protect the beets from frost and yet prevent their growth in the silo until the spring. The beets are removed from the silo at an early date in the spring and are immediately subjected to analysis for the final selection. In the early days of the beet industry the beets were selected almost solely on account of their specific gravity. A brine of a given strength was made and the beets, thoroughly cleaned of dirt, were thrown into this brine. Those which would sink were selected as mothers while those that would swim were rejected. Selection now depends upon the actual determination of the density of the juice of the beet which is to be selected as a mother and the estimation of its content of sugar. For this purpose a cylindrical or conical piece of the beet is removed, by

an appropriate instrument, diagonally through the center of the root. This piece may weigh from 1½ to 2 ounces, and its removal does not injure the beet for germinating purposes. The juice is expressed from this piece, and its specific gravity determined by weighing in it, at a given temperature, a silver button of known weight.

The sugar content of the juice is next determined by means of the polariscope. By means of these two data the qualities of the beet for the production of seed are determined and also the coefficient of purity, that is, the number obtained by dividing the percentage of sugar in the juice by its percentage of solid matters as determined by its specific gravity. In mother beets this number should be found somewhere between 80 and 90. The actual method of selection may be illustrated as follows:

The operator determines beforehand his standard, which in most cases will consist of a juice containing 16 to 18 per cent. of sugar, with a purity of 85. The beets are analyzed separately, and are at once divided into two great classes, namely, those in which either the content of sugar or the purity falls below the fixed figure, and, second, those in which these two numbers are equal to or exceed the fixed figures. It is sometimes customary to divide these two classes into two portions, viz., those roots in which the numbers are equal to or slightly above the standard, and, second, those which show exceptional richness. It is also customary to number each beet, and the number, which is cut into the skin of the beet, will remain legible even after the seed has ripened. Some of the producers of sugar-beet seed preserve the product of seed from each beet by itself, and do not use it for the production of seed for commerce until it has received an additional year's trial.

By this method of careful, scientific culture the sugar beet has been raised to its present high standard of excellence, and is only maintained at this standard by constant supervision, such as is indicated.

The sugar-beet seed produced by the above method is not sold for planting fields, but is used solely for the production of the seed of commerce in the fourth or fifth year from the parent, as the case may be.

MANUFACTURE OF SUGAR.

The process of making sugar from the sugar beet interests the agriculturist only from secondary considerations, and will be treated of in the briefest possible manner to give an intelligent idea of its methods.

The beets are first conveyed to washing-tanks provided with suitable apparatus for keeping them in motion and transferring them toward the end from which the fresh water enters, in order that the whole of the adhering soil, together with any sand and pebbles, may be completely removed. By a suitable elevator the beets are next taken to a point above the center of the battery, whence they are dropped into a slicing apparatus by which they are sliced into pieces of greater or less length and of small thickness, so that when placed in the cells of the

battery they will not lie so closely together as to prevent the circulation of the diffusion juices. The slices, commonly called cossettes, next pass into the diffusion battery in which the sugar is extracted in the usual way. The extracted cossettes are carried through a press by which a portion of the water is removed, and they are then in suitable condition for use as cattle food. The diffusion juices are carried to carbonatation or saturation tanks, where they are treated with from 2 to 3 per cent of their weight of lime and afterward with carbonic acid until nearly all of the lime is precipitated. The slightly alkaline juices are next passed through filter presses by which the precipitated lime and other matter are removed. The juices pass next to a second set of carbonatation tanks in which they undergo a treatment in each particular similar to the one just mentioned, except that the quantity of lime added to the second saturation is very small as compared with that of the first. The refiltered juices from the second saturation are carried to the multiple-effect vacuum-pan and reduced to the condition of sirup. The sirups are taken into the vacuum strike pan and reduced to sugar called masse cuite, containing from 6 to 10 per cent of water. The uncrystallized sirups together with the water are separated from the sugar by the centrifugals, and form the molasses. The molasses is either reboiled and a second crop of crystals obtained, or is treated in various ways for separating the sugar which it still contains. One of these methods which has come into general use is known as the Steffen process. Another method consists in separating the salts which prevent the crystallization of the sugar by the process of osmosis. A third method consists in the use of strontium salts for the separation instead of lime salts as in the Steffen process; or, finally, the molasses may be subjected to fermentation and distillation and the sugar therein contained thus converted into alcohol.

The above is the general method used for the manufacture of raw sugar. If refined sugar is to be made the juices and sirups are passed over bone-black to decolorize them and the crystals are washed in the centrifugal in order to make them perfectly white. Another method consists in treating the juice with sulphurous acid and purifying the crystals by washing them with sirups of varying degrees of consistency until all the molasses adhering thereto is washed away.

The question is often asked if beet sugar can not be made in a small way so that 6 or 7 farmers could club together, put up a cheap apparatus and produce their own sugar. On account of the elaborateness of the process and the costly nature of the machinery which is necessary to produce beet sugar even in a small way, it is not believed that it could be profitably made in the way indicated. A small factory could not possibly compete with a large one and hence there is no encouragement to be offered in the way of producing beet sugar in a small factory. The Department has no knowledge of any successful beet-sugar factory of this kind. There is no country producing any notable quantity of beet sugar in which home apparatus costing only a few thousand dol

lars have any appreciable influence on the output of sugar. Russia has been cited as an exception to this rule. The output of beet sugar in Russia annually is about 500,000 tons. The total number of factories in operation about 250. The average annual output of each factory in round numbers is 4,000,000 pounds, representing an average consumption of 20,000 tons of beets. From these figures, taken from official data, it is seen that the average size of the Russian beet-sugar factory is not greatly different from those of other European countries.

The waste products of the factory consist of the pulps and molasses. The molasses is used for various purposes; either for fertilizing purposes or for the manufacture of alcohol, or sometimes for cattle food. The pulps make a valuable cattle food. They may be fed in the fresh state or preserved in silos. Lately extensive experiments have been made in drying the pulps and preserving them in the dried state, and these experiments have been fully successful. It is stated that the value of the pulps for feeding purposes is from one-fourth to one-fifth of the value of the beets.

The cost of manufacture depends on as many factors as that of beet growing. Chief among these are transportation, fuel, weather, and labor. Perhaps the most important of these factors is the price of fuel. In some localities coal can be had for $1.25 per ton; in others the cost may reach as high as $10 per ton.

The manufacture of beet sugar is still so much of an experiment in this country as to render any exact account of its cost impossible. To show what it may be, with large experience and the highest skill and management, I give the mean cost of manufacture in 113 German factories from data of the campaign of 1889–'90.

Mean capital invested in each factory		$193,400.00
Total receipts for sugar, molasses, and pulps per ton of beets		11.10
Mean cost of beets per ton of 2,220 pounds	4.90	
Salaries per ton of beets	.26	
Labor per ton of beets	.73	
Interest on investment per ton of beets	.36	
Coal per ton of beets	.63	
Miscellaneous expenses per ton of beets	.96	
Total expense of manufacture per ton		7.84
Profit per ton of beets		3.26

The mean net profit for each factory was $34,240. The price paid for beets, however, is in most cases fictitious, the beet growers owning the factory and preferring to share in the general profits rather than charge a high price for the beets. First-class beets rarely sell for less than $5.25 per ton. The Western Beet Sugar Company, of Watsonville, California, stated that in its first campaign, 1888–'89, the cost of making sugar amounted to $80.80 per ton. At the present time it appears that with the best machinery and most economical processes beet sugar can be made in this country at a cost of from 4 to 5 cents per pound.

STATISTICAL.

THE GERMAN CAMPAIGN OF 1888–'9.

During this campaign the new law levying a part of the tax on the beets and a part on the sugar produced came into operation for the first time. The object of this law is to diminish the bounty paid on exports. By the new law the tax on the beets has been reduced to .80 marks per 100 kilograms, instead of 1.7 marks as by the former law. On the other hand, sugars entering consumption pay 12 marks per 100 kilograms, whereas before they paid nothing when made from native beets.

The quality of the beet root harvested in 1888–'89 was much inferior to that of the preceding year, owing to a late, wet spring and an excess of rain in June and July. The yield of sugar was also diminished by early frosts. As the juice of frosted beets was boiled with extreme difficulty, being difficult to filter and granulate, many factories would not accept them.

The following table, according to M. Licht,* gives the actual production of sugar in Germany in metric quintals† and the percentage of yield on the weight of the beet from 1871 to 1889:

Year.	Real production.	Actual yield.	Year.	Real production.	Actual yield.
		Per ct.			*Per ct.*
1871–'72	1,864,419	8.28	1880–'81	5,730,214	9.06
1872–'73	2,625,511	8.25	1881–'82	6,222,885	9.92
1873–'74	2,910,407	8.25	1882–'83	8,489,226	9.71
1874–'75	2,564,124	9.30	1883–'84	9,606,093	10.77
1875–'76	3,580,482	8.60	1884–'85	11,467,303	11.02
1876–'77	2,909,227	8.19	1885–'86	8,381,049	11.85
1877–'78	3,805,091	9.30	1886–'87	10,237,339	12.32
1878–'79	4,301,551	9.35	1887–'88	9,591,184	13.77
1879–'80	4,154,152	8.64	1888–'89	9,904,776	12.55

DEVELOPMENT OF THE CANE AND BEET SUGAR INDUSTRY.‡

The following table expresses in tons of 2,200 pounds the amounts of cane and beet sugar made in the world during the past 7 years:

Year.	Beet.	Cane.	Total.
1883–'84	2,361,000	2,323,000	2,684,000
1884–'85	2,546,000	2,351,000	4,897,000
1885–'86	2,220,000	2,340,000	4,560,000
1886–'87	2,730,000	2,345,000	5,075,000
1887–'88	2,452,000	2,470,000	4,922,000
1888–'89	2,765,000	2,280,000	5,045,000
1889–'90	3,500,000	2,278,000	5,778,000

It is seen from the above table that the production of cane sugar has remained stationary or even diminished during the last septennial period, while the production of beet-sugar has greatly increased.

* Sugar, April, 1890, p. 46.

† Divide by 10 to get tons of 2,200 pounds each.

‡ La Sucrerie Indigene, March 11, 1890, p. 232.

Willet and Gray (Louisiana Planter and Sugar Manufacturer, April 5, 1890) give the following estimate of the total sugar crop of the world, in tons, for the last 5 years:

Country.	1889–'90.	1888–'89.	1887–'88.	1886–'87.	1885–'86.
Cuba	600,000	530,000	610,000	608,900	705,400
Porto Rico	70,000	55,000	50,000	86,000	64,000
Trinidad	60,000	60,000	60,000	69,000	49,200
Barbadoes	60,000	50,000	60,000	65,000	44,000
Jamaica	30,000	28,000	30,000	21,000	17,000
Antigua and St. Kitt's	28,000	25,000	26,000	25,000	25,000
Martinique	40,000	38,000	39,000	41,000	33,000
Guadeloupe	50,000	45,000	50,000	55,000	37,000
Demerara	125,000	108,000	110,000	135,000	111,800
Réunion	30,000	25,000	32,000	32,000	35,000
Mauritius	125,000	132,000	120,000	101,800	114,200
Java	310,000	364,000	396,000	363,950	365,950
British India	60,000	60,000	55,000	50,000	50,000
Brazil	150,000	220,000	320,000	260,000	186,000
Manila, Cebu, and Iloilo	180,000	210,000	174,000	180,000	186,000
Louisiana	125,000	145,000	158,000	80,900	127,000
Peru	30,000	30,000	30,000	26,000	27,000
Egypt	35,000	35,000	35,000	50,000	65,000
Sandwich Islands	120,000	120,000	100,000	95,000	96,500
Total of cane	2,228,000	2,254,000	2,465,000	2,345,550	2,339,950
Total of beet	3,550,000	2,753,844	2,451,950	2,730,206	2,219,973
Cane and beet	5,778,000	5,007,844	4,916,950	5,075,756	4,559,923

La Sucrerie Belge of March 15, 1890, page 372, gives the following estimate of the total production of beet sugar in Europe during the past four years, in tons of 2,200 pounds:

Country.	1889–'90.	1888–'89.	1887–'88.	1886–'87.
Germany	1,220,000	978,000	953,400	1,015,600
Austria	730,000	514,000	400,000	550,000
France	750,000	460,000	420,000	497,000
Russia	445,000	503,000	430,000	455,000
Belgium	172,000	96,000	93,000	91,000
Holland	55,000	35,000	37,000	36,000
Denmark	20,000	19,000	21,000	18,300
Other countries	25,000	21,000	14,000	13,000
Total	3,417,000	2,626,000	2,368,400	2,675,900

STATISTICS OF THE PRODUCTION OF CANE AND BEET SUGAR.

Licht, of Magdeburg, in his last report (Journal des Fabricants de Sucre, March 26, 1890), gives the following figures for the production of beet sugar in Europe for the last three campaigns:

[In tons of 2,200 pounds.]

Country.	1887–'88.	1888–'89.	1889–'90.
Germany	956,166	990,604	1,260,000
Austria	428,616	523,242	750,000
France	392,821	466,767	775,000
Russia	441,342	525,387	475,000
Belgium	140,742	145,804	200,000
Holland	39,280	46,040	60,000
Other countries	79,980	87,000	80,000
Total	2,481,950	2,784,844	3,600,000

CONSUMPTION OF SUGAR IN THE UNITED STATES.

Imported during the year ending July 1, 1890.

	Pounds.	Value.		Gallons.	Value.
Sugar, duty free	224,457,011	$11,549,828	Molasses:		
Beet sugar, duty paid	601,119,476	18,348,417	Duty free	81,443	$9,314
Cane sugar, duty paid	2,108,435,073	66,196,287	Duty paid	31,415,800	5,168,795
Total	2,934,011,560	96,094,532	Total	31,497,243	5,178,109

Adding to total imports the domestic production, in round numbers 300,000,000 (287,490,271 in Louisiana alone), gives the total sugar in this country for the year ending July 1, 1890, 3,134,011,560 pounds. This number divided by 63,500,000 gives a trifle over 51 pounds per head for the consumption of sugar in the United States. Other estimates make it about 55 pounds per head.

The crop of molasses in Louisiana was 18,431,988 gallons. The production of sorghum and maple molasses and starch sugar sirup can only be estimated, but can safely be put at 30,000,000 gallons, making the total consumption of molasses 79,928,231 gallons.

Consumption of sugar per head for the principal countries during the year 1887.

	Kilogrammes.	Pounds.		Kilogrammes.	Pounds.
Finland	0.60	1.32	German Empire	8.60	18.92
Roumania	1.50	3.30	Belgium	7.14	15.71
Servia	2.00	4.40	Sweden	7.95	17 49
Spain	2.32	5.11	France	12.30	27.06
Italy	3.45	7.59	Switzerland	10.35	22.77
Russia	4.10	9.02	Holland	10.50	23.10
Portugal	4.34	9.55	Denmark	13.47	29.63
Norway	5.16	11.35	Argentine Republic	22.70	49.94
Austria and Hungary	5.50	12.10	Great Britain	32.00	70.40

With free sugar, as provided for by the present tariff, it is estimated that the consumption of sugar in the United States will speedily equal that of Great Britain. At 70 pounds per head, and with a population of 64,000,000, this would amount to 4,480,000,000 pounds annually. It is safe to predict that within 5 years this quantity of sugar will be required for the annual supply of our people. The home market, therefore, for many years to come can not hope to find its supplies in the home product.

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